Errata

Document Title: How to Get More Output Power from a Comb Generator Module with the Right Bias Resistance (AN 984)

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HP References in this Application Note

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APPLICATION NOTE 984

How To Get More Output Power From a Comb Generator Module With the Right Bias Resistance

INTRODUCTION

Comb generator modules, models 33002B, 33003B, 33004B and 33005D, are specified for minimum power output over a broad frequency range. Each unit is tested with a short circuit DC return. By substituting an optimum value of resistance for the DC return, these specified values of power output may be doubled.

These modules are used to generate a comb of frequencies — multiples of the drive frequency. In the time domain, a comb generator is called an impulse generator. A voltage impulse is generated once per cycle of the drive frequency. In the frequency domain, this waveform is equivalent to harmonics of the drive frequency. The relative amplitude of these harmonics is related to the width of the impulse.

Step recovery diode impulse generators include an inductance in series with the diode. The voltage impulse is formed when the diode resistance, controlled by charges in the I layer, suddenly changes from a low to a high value. The corresponding current change in the inductance generates a spike of voltage.

Analyses of a step recovery diode comb generator usually include a negative bias voltage on the diode.[1] Figure 1 shows how this bias voltage appears to be necessary so that the charge stored by the forward current is removed by the reverse current at the time corresponding to the peak current. It appears that the impulse generated by the sudden change of current would not appear if the bias were removed. Since the charge is the area under the current curve, a half cycle of reverse current would be required to remove the charge injected by the half cycle of forward current. The current would then be zero so no impulse could be formed.

Although it is true that optimum performance of an impulse generator does require the proper value of bias voltage, step recovery diodes work quite well with a zero ohm DC return which assures zero bias voltage. More detailed analysis[2] shows that the forward current is not sinusoidal and the peak current is lower than the peak reverse current. Figure 2 shows how the reverse current removes the charge before returning to zero even when zero bias is used.

One way of optimizing the bias voltage is the choice of bias resistor. In this mode of operation the reverse bias voltage is generated by rectified current flowing through the bias resistor. Compared to zero bias operation, power output can be improved by a factor of two to four.

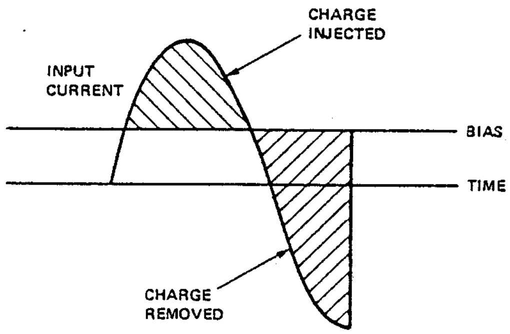

Figure 1. Step Recovery Diode Charge Behavior with Sinusoidal Current

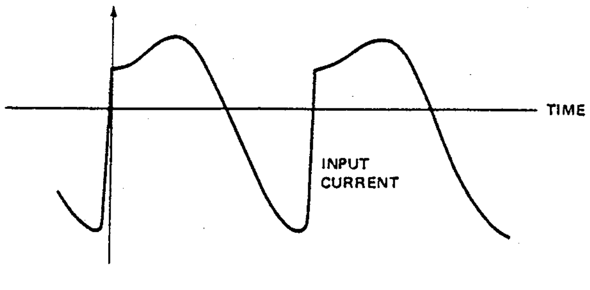

Figure 2. Distorted Forward Current in Step Recovery Diodes

MEASUREMENTS

A study was made of the effect of bias resistance in a comb generator module similar to Hewlett Packard model 33005D. Input power was 500 milliwatts. The optimum bias resistance was 200 ohms for most harmonics. In all cases the output with 200 ohms bias resistor was within one dB of the output with optimum bias resistor. The output power improvement compared to zero bias was at least 2.5 dB and in some cases as high as 6 dB. The bias voltage is generated by rectified current through the bias resistor so a larger optimum resistor would be expected with higher input frequencies. This would compensate for less rectification when the period is far from the diode lifetime.[3]

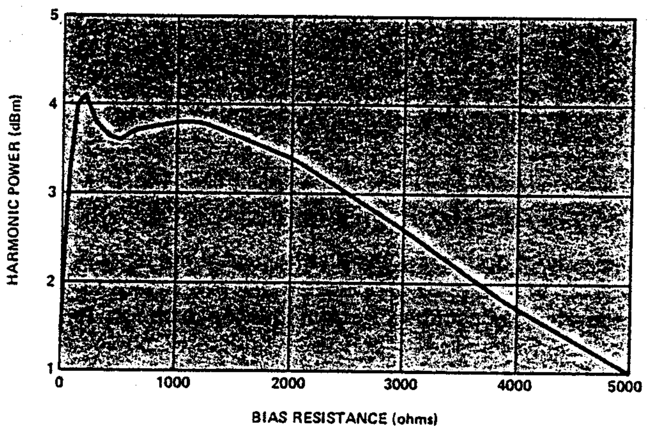

Figure 3. Effect of Bias Resistance (Fourth Harmonic)

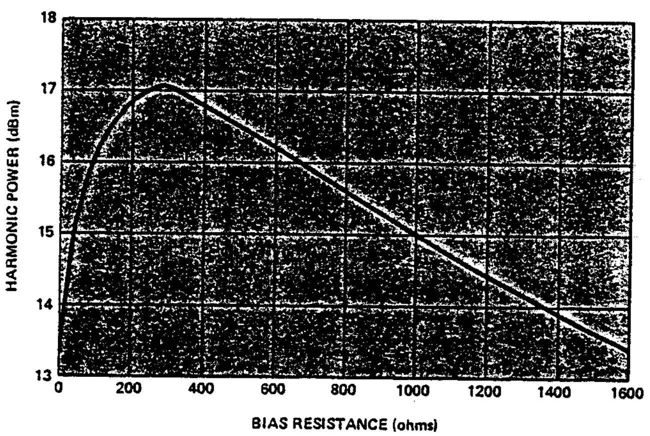

Figure 4. Effect of Bias Resistance (Second Harmonic)

Figure 3 shows the effect of bias on the 4th harmonic output power. The optimum bias resistance is 200 ohms but the value is not critical. Power output is within 1 dB of the peak from 60 ohms to 2300 ohms. This behavior is typical for harmonics above the 3rd.

Figure 4 shows the effect of bias resistance on the 2nd harmonic. Third harmonic behavior is similar. The slope is steeper for these lower order harmonics.

TEMPERATURE COMPENSATION

The optimum value of bias resistance changes with temperature at a rate of about 1% per degree C. In some applications, then, bias resistance values close to a steep slope of the power vs resistance curve should be avoided. For example, the optimum room temperature value of 200 ohms in Figure 3 would be a poor choice if the system must operate at high temperatures. The optimum resistance would then be much higher and power output at 200 ohms resistance would be several dB down. It would be better to use 1000 ohms, accepting a slight degradation from the peak in exchange for a flat response.

A simple way to avoid this temperature variation is the use of temperature sensitive resistors (sensistors) in the bias circuit.[2] The reason for the change in optimum bias resistance value with temperature is the variation of lifetime with temperature.

CONCLUSION

Power output in a comb generator can be doubled by using an appropriate bias resistor. With a half watt input level near 1 GHz, the optimum resistance is about 200 ohms. Higher values of resistance would be needed for higher input frequencies or lower input power.

REFERENCES

1. Harold T. Friis, "Analysis of Harmonic Generator Circuits for Step Recovery Diodes", *Proc. IEEE*, Vol. 55, No. 7, July 1967, pp. 1192-1194.
2. Stephen Hamilton and Robert Hall, "Shunt-Mode Harmonic Generation Using Step Recovery Diodes" *Microwave Journal*, Vol. 10, No. 4, April, 1967, pp. 69-78.
3. Hewlett-Packard Components Application Note 957-3, Rectification Effects in PIN Attenuators.

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